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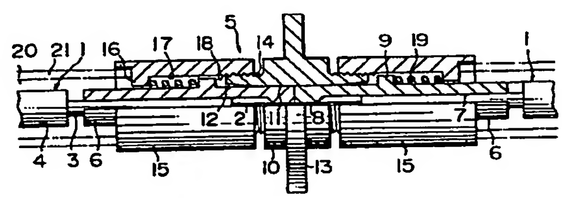
(54) Optical fiber connector and method of producing same.

(57) An optical fiber connector (5) comprising a pair of plugs (6), a sleeve (10) and a pair of cap nuts (15) which is assembled at the site where optical fibers are installed, so as to connect the optical fibers with a high degree of positional accuracy. The plugs and the sleeve are molded of a composition including a synthetic resin added with a suitable content of a filler, such as glass beads.



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OPTICAL FIBER CONNECTOR AND METHOD OF PRODUCTING SAME

BACKGROUND OF THE INVENTION

This invention relates to an optical fiber connector for connecting optical fibers together which are used as fiber-optic links in an optical communications system and a method of producing same.

An optical information transmitting system or optical communications system has been developed as a promising system that would take over the electrical information transmitting system now widely in use. In an optical communications system, pulses of light generated on the transmission side are transmitted down fibers of glass or optical fibers of a thickness of one hundred to several hundreds of μm to the receiving side at which the pulses of light are converted into electric signals and taken out.

In this type of optical communications system, the most important problem is how to transmit information from the transmission side to the receiving side with a high degree of efficiency in a stable manner.

In the optical communications system, a loss of light would occur in the connections of optical fiber connectors for connecting together the optical fibers forming links and built into telephone trunk networks, for example, for transmitting signals. Advances made in the progress of art have made it possible to reduce

the loss occurring within the optical fibers to the range between a fraction of and 1 dB/km. In the optical fiber connectors, however, the loss that might occur has its size decided by the amount of eccentricity of the axes of a pair of optical fibers abutted against each other by an optical fiber connector. For example, in the case of an optical fiber of 125 μm in diameter, if the axes of the optical fibers abutted against each other are off-center by about 4 μm, a connection loss of about 0.5 dB would occur; if the eccentricity is about 7 μm, the loss would be 1 dB.

Thus the present practice in transmitting information over a long distance by utilizing an optical communications system is to mount repeaters in the fiber-optic links at suitable intervals of space for amplifying signals that have been attenuated, before being transmitted to the destination. In this case, if the connection loss occurring in the optical fiber connectors is high, it would become necessary to increase the number of repeaters. An increase in the number of repeaters is not only undesirable from the economical point of view but also gives rise to many problems because it makes it necessary to perform maintenance and inspection more often and might reduce the reliability of the optical communications system as a whole.

The optical fibers may vary from one another in length depending on the locations at which they are installed or the channels through which information is

transmitted. Thus the operation of attaching a connector to the terminal ends of the optical fibers has been required to be performed readily at the site of installation.

Accordingly the optical fiber connector should meet the requirements of low connection loss and easy assembly.

The optical fiber connector usually comprises a plug formed with a flange in an intermediate portion on its outer peripheral surface and a bore for containing an optical fiber in its center axial portion, a sleeve formed at its center axis with a through hole for fitting the outer peripheral surface of the plug and on its outer peripheral surface with threads, a cap nut adapted to threadably engage the thread generated in the sleeve, and a spring mounted between the plug and the cap nut for keeping constant the abutting force exerted by the plug. The accuracy in positioning an optical fiber owes largely to the accuracy in positioning the plug and sleeve relative to each other. In this respect, what is most important is how to minimize deviation of the axis of the plug from the axis of the optical fiber.

To this end, two types of plugs have hitherto been developed. One type has its outer case formed of hard metal which has a double eccentric cylinder built therein and the other type has a guide of jewels or ceramics embedded in the center axis and formed with a

bore of a diameter slightly greater than that of the optical fiber.

In the plug of the type having the double eccentric cylinder, positioning of the optical fiber with respect to the center axis of the plug is effected by moving the two eccentric cylinders while making observations with a microscope after the optical fiber is fixed to the eccentric cylinders in the central portion of the plug. Thus this type has the disadvantage of being very poor in operability.

The plug having a guide embedded therein has the forward end of the optical fiber positioned by the guide, so that this type offers the advantage of the operability at the site of installation being greatly improved. However, working of the plug or aperturing the guide on the order of a fraction of millimeter would require highly advanced skills and a prolonged time for consummation, so that the operation would be very low in productivity.

SUMMARY OF THE INVENTION

An object of this invention is to provide an optical fiber connector enabling optical fibers to be assembled readily and with a high degree of precision at the site of installation at which connection of optical fibers is required to be effected.

Another object is to provide a method of producing an optical fiber connector enabling the optical

fiber connector to be assembled readily and with a high degree of precision at the site of installation.

The aforesaid objects are accomplished according to the invention by providing the features that the sleeve and the plug constituting an optical fiber connector are molded of the same synthetic resin and that when the plug is shaped the bore for receiving an optical fiber is molded by a projection on an end surface of the core pin constituting the abutting end of the plug.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a front view, with certain parts being shown in section, of the optical fiber connector comprising one embodiment of the invention;

Fig. 2 is a sectional front view showing the essential portions of a mold for molding a plug;

Fig. 3 is a sectional front view of the plug;

Fig. 5 is a sectional front view of the sleeve;

Fig. 6 is a characteristic diagram showing the clearance provided in fitting the plug to the sleeve in relation to the force with which the plug is inserted and withdrawn and the connection loss;

Fig. 7 is a characteristic diagram showing the number of times the plug is inserted and withdrawn in relation to the connection loss;

Fig. 8 is a characteristic diagram showing the temperature decided by the selected material for molding the plug and the sleeve in relation to the

connection loss; and

Fig. 9 is a view, on an enlarged scale, showing the optical fiber connector comprising another embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the invention will now be described by referring to the accompanying drawings. Fig. 1 shows an optical fiber connector 5 comprising one embodiment of the invention being used for connecting the optical fibers. An optical fiber cable 1 comprises an optical fiber 2 for transmitting light signals, a primary coat 3 for reinforcing the optical fiber 2, and a secondary coat 4 overlying the primary coat 3. The optical fiber connector 5 includes a plug 6 molded cylindrically in such a manner that a bore 7 for receiving the optical fiber cable 1 from which the secondary coat 4 is removed and an orifice 8 for receiving the optical fiber 2 communicate with each other in the center axis of the plug 6. A flange 9 is formed in the central portion of the outer peripheral surface of the plug 6. A sleeve 10 has molded therein with a through hole 11 for receiving the plug 6 which has divergingly tapering guide portions 12 located at opposite ends and diverging toward the openings of the hole. The sleeve 10 is molded on its outer peripheral surface with a flange 13 in the central portion and threads 14 at either end. A cap nut 15 is molded cylindrically and has a through hole 17 molded therein which slidably receives the plug

6 and has a flange 16 located opposite the flange 9. The through hole 17 is molded at one end with threads 18 for engaging the threads 14 molded in the sleeve 10. A spring 19 is attached to the outer periphery of the plug 6 so as to be interposed between the flanges 9 and 16. The plug 6 and the secondary coat 4 of the optical fiber cable 1 are connected together as a unit by a clamp ring 20 and a cable cap 21, so as to avoid an inserting and withdrawing force being exerted on the optical fiber 2 when the plug 6 is inserted and withdrawn with respect to the sleeve 10.

In the aforesaid construction, the optical fiber connector 5 is assembled as follows. The optical fiber cable 1, plug 6, sleeve 10, cap nut 15, spring 19, clamp ring 20 and cable cap 21 are molded in the respective shapes at the plant and transported to the site of installation individually. At the site of installation, the cable cap 21, clamp ring 20, cap nut 15 and spring 19 are inserted in the indicated order in the end of the optical fiber cable 1 and moved to the position where they do not interfere with operations. Then, after removing the secondary coat 4 and the primary coat 3 from the end of the optical fiber cable 1 to a position spaced apart from the end by a predetermined length, the optical fiber 2 of the optical fiber cable 1 that has had sheaths is washed with an organic solvent. Meanwhile an adhesive agent is inserted in suitable amount into the bore 7 and orifice 8 of the plug 6. Then the

optical fiber cable 1 is inserted at one end into the bore 7 of the plug 6 and forced thereinto until the optical fiber 2 projects from the orifice 8 a suitable length. Following setting of the adhesive agent, the forward end portion of the plug 6 is fixed and the cap nut 15 is moved toward the front end of the plug 6 as long as the spring 19 is compressible, to be locked therein. Thereafter, the clamp ring 20 is positioned such that one end thereof is applied to the plug 6 and the other end thereof is applied to the secondary coat 4 of the optical fiber cable 1, and the clamp ring 20 is adhesively attached to the plug 6 and the secondary coat 4. In like manner, the cable cap 21 is adhesively attached to the secondary coat 4. Then, the cap nut 15 is released and returned toward the center of the optical fiber cable 1 by the biasing force of the spring 19. The portion of the optical fiber 2 projecting from the forward end of the plug 6 is severed so that the optical fiber 2 will match the plug 6 at their ends. The plug 6 is inserted in a jig for lapping to grind the forward end portion of the plug 6. After it is subjected to lapping until a required surface roughness is attained, the plug 6 and the optical fiber 2 have their surfaces washed. Then, the plug 6 is fitted in the sleeve 10 and clamped by the cap nut 15, thereby completing connection of the optical fiber cable 1 by the optical fiber connector 5.

The bore 7 of the plug 6 and the space

between the optical fiber 2 and the primary coat 3 as well as the space between the orifice 8 and the optical fiber 2 are filled with an adhesive agent.

The sleeve 10 and the cap nut 15 of the optical fiber connector 5 are molded by a shaping process known in the art.

The plug 6 is molded with a mold shown in Fig. 2 in its essential portions only. The portions of the mold not shown are similar to those of a known mold of the triad construction.

Referring to Fig. 2, an lock pin 31 projects from a stationary mounting plate 30, and a stationary cavity retainer plate 32 has a stationary cavity 33 for defining the outer periphery of the forward end portion of the plug 6 embedded therein and having at one end thereof a stationary core 34 defining the forward end face of the plug 6 embedded therein. The stationary core 34 is formed therein with air vents 35 for evacuating a cavity for defining the plug 6, and a dummy cavity 36 communicating with the air vents 35 and storing therein the air from the aforesaid cavity. A stationary core pin 37 slightly thicker than the optical fiber 2 of the optical fiber cable 1 projects from the end face of the stationary core 34 at its central portion. A movable cavity retainer plate 38 has embedded therein a movable cavity 39 for defining the flange 9 of the plug 6 and the outer periphery of the rear end thereof. The movable cavity retainer plate 38 and the movable cavity 39 have a

groove 40 of the disc shape formed therein for providing a runner of the disc shape between the movable cavity retainer plate 38 and the stationary cavity retainer plate 32, and an annular gate is provided between an annular projection 41 formed on the movable cavity 39 and the stationary cavity retainer plate 32. The movable cavity 39 has an ejector pin 42 slidably inserted therein for defining the rear end face of the plug 6. The ejector pin 42 has slidably inserted in its center axis a movable core pin 43 having a diameter larger than the outer diameter of the secondary coat 4 of the optical fiber cable 1, so that when the mounting plates are clamped together the forward end of the movable core pin 43 abuts against the stationary core pin 37.

In this construction, when the mounting plates are clamped together and a synthetic resin 44 is fed from a molding machine to the runner, the synthetic resin 44 flows into the cavity defined by the stationary cavity 33, stationary core 34, stationary core pin 37, movable cavity 39, movable core pin 43 and ejector pin 42 after passing through the gate following filling of the runner, to form the plug 6. At this time, the air failed to be released through the interface between the mounting plates and gaps between the parts flows through the air vents 35 to be forced into the second cavity. After the resin has set, the mounting plates are released from each other. First of all, the movable cavity retainer plate 38 is moved rearwardly. This moves the molded

plug 6 together with the movable cavity retainer plate 38. At this time, the synthetic resin in the air vents 35 is ruptured, to separate the plug 6 from the synthetic resin in the second cavity. Rearward movement of the movable cavity retainer plate 38 actuates the ejector pin 42 which ejects the plug 6 from the movable cavity 39 and the stationary core pin 37. At the same time, the stationary cavity retainer plate 32 moves together with the movable cavity retainer plate 38, to be separated from the stationary mounting plate 30. Then the synthetic resin set in the second cavity catches against the lock pin 31 and remains on the stationary mounting plate 30, so that the synthetic resin set in the air vents 35 and the dummy cavity 36 of the stationary core 34 can be removed. While the parts are in this condition, the synthetic resin that has set is removed from the lock pin 31.

By molding the plug 6 by using a core pin attached to the core for defining the forward end face of the plug 6 for molding the orifice 8 for receiving the optical fiber 2 of the optical fiber cable 1, it is possible to achieve positioning of the orifice 8 with respect to the plug 6 with a very high degree of precision. The provision of the second cavity is conducive to increase dimensional accuracy of the forward end portion of the plug 6.

The plug 6 may be molded of either a thermosetting resin or themoplastic resin. When a synthetic

resin is used singly, the hardness thereof is very low with respect to the optical fiber 2 of the optical fiber cable 1. The result of this would be that the length of the optical fiber 2 sticking out of the end face of the plug 6 would be large when the end face of the plug 6 is lapped. To cope with this situation, a filler of inorganic material may be added to the synthetic resin to increase the hardness of the plug 6. The filler may be selected from the group consisting of glass beads, glass balloon, volcanic glass, metals, such as aluminum, iron, etc., and their oxides, graphite and calcium carbonate.

Example 1

The plug 6 was molded by using a mold shown in Fig. 2 and tested for its dimensions and connection characteristics as shown in Figs. 3 and 4, to pass judgement on whether or not the plug 6 is acceptable for specifications. Polycarbonate which is commercially available was used as the synthetic resin and the filler was selected from the group consisting of glass fibers, carbon fibers and glass beads of a mean particle size of 10 µm.

The subjects of tests are as follows:

(1) Out of roundness of the forward end portion of plug 6.

(2) Concentricity (amount of eccentricity) of the center axis of orifice 8 with respect to the center axis of plug 6.

(3) Shrinkage S between flange 9 and the forward end of plug 6 for a length ℓ (Fig. 3) or contraction of outer periphery of plug 6 (straightness).

(4) Surface roughness of plug 6.

(5) Difference h between the forward end face of plug 6 and the forward end of optical fiber 2 after assembling and lapping (mean value, maximum value and minimum value).

(6) Connection loss of optical fiber connector 5.

The standards by which judgment was passed were connection loss of below 1 dB and the distance between the end face of plug 6 and the end of optical fiber 2 of below 4 μm at the maximum. The results of the tests are shown in Table 1. The connection loss shown in Table 1 (and Tables 2-4) was determined with a fitting clearance 0 between plug 6 and sleeve 10.

Table 1

Item / Specimen	Filler		Dimentional Accuracy (μm)						Connection Loss (dB)	Overall Results
	Kind	Content (%)	Out of Roundness	Concentricity	Straighness	Surface Roughness	Spacing between Ends of Plug and Optical Fiber			
							Mean Value	Variations		
A		0	2.8	4.5	5.8	1.8	14.5	2-18	1.1	Poor
B	Glass Fibers	30.0	14.8	6.5	8.5	6.0	4.0	2-7	1.1	Poor
C	Carbon Fibers	30.0	8.2	7.6	13.5	5.4	4.5	3-8	1.5	Poor
1	Glass Beads	2.5	2.8	3.5	5.6	1.8	13.0	2-15	0.95	Poor
2	"	4.7	2.9	3.4	5.5	1.9	10.5	3-13	0.95	Poor
3	"	5.2	2.9	3.4	5.5	1.8	4.5	2-5	0.85	Poor
4	"	9.5	3.0	2.9	5.4	-	3.5	2-4	0.80	Excellent
5	"	15.6	-	2.9	4.5	1.9	3.0	1-4	0.50	Excellent
6	"	25.0	3.1	2.3	3.0	2.2	2.0	1-3	0.70	Excellent
7	"	30.2	3.2	2.1	2.5	2.3	1.5	0-2	0.65	Excellent

In Table 1, it will be seen that the mixture of polycarbonate with 9.5-30.2 wt% of glass beads as a filler is suitable for producing an optical fiber connector. Besides glass beads, glass balloons or silica glass may be used as a filler.

It has been ascertained that when glass beads were added in over 30-odd %, the plug 6 produced showed deterioration in mechanical properties or molding of the plug 6 was made impossible.

It is essential that the glass beads be uniformly distributed in the polycarbonate when the mixture is produced. Thus in actual practice, the proportion of the glass beads added to the polycarbonate is preferably 10-30%.

Meanwhile when the optical fiber connector 5 is in service, the plug 6 is repeatedly inserted into and withdrawn out of the sleeve 10. In applications where the number of times of insertion and withdrawing is large, it is desired that the wear caused between the plug 6 and sleeve 10 be minimized. To this end, of all lubricants, polytetrafluoroethylene (PTFE) and molybdenum disulfide (MoS_2) were mixed and the results of lubrication achieved by using the mixture were determined.

In addition to the subjects of tests described hereinabove with respect to the plug 6 molded of the mixture of polycarbonate and a filler, the connection loss was tested following insertion and withdrawing performed for 200 times. To the standards of judgment

described hereinabove, a connection loss of less than 0.2 dB following the insertion and withdrawing of 200 times was added for the connection loss occurring in initial periods.

The mixture used for molding the plug 6 contained polycarbonate and 30 wt% of glass beads.

The results of the tests are shown in Table 2.

Table 2

Item / Specimen	Filler		Dimensional Accuracy (μm)					Connection Loss (dB)		Overall Results
	Kind	Content (%)	Out of Roundness	Concentricity	Straightness	Surface Roughness	Variations Spacing between Ends of Plug and Optical Fiber	Initial Stage	After Insertion and Withdrawing	
A		0	2.8	4.5	5.8	1.8	2-18	1.10	1.45	Poor
8	PTFE	2.5	2.8	2.1	5.0	1.8	0-2	0.65	1.00	Poor
9	"	4.2	-	2.1	5.0	1.8	0-2	0.65	0.90	Poor
10	"	5.0	2.8	2.1	-	1.8	0-2	0.65	0.85	Excellent
11	"	10.0	2.8	-	4.9	1.9	0-2	0.65	0.80	Excellent
12	"	20.0	2.9	2.2	5.0	2.0	0-2	0.68	0.75	Excellent
13	"	30.0	2.9	2.2	4.9	2.1	0.2	0.68	0.75	Excellent
14	MoS_2	0.5	2.8	2.1	5.0	1.8	0-2	0.65	0.95	Poor
15	"	0.8	2.8	-	5.0	1.8	0-2	0.65	0.85	Excellent
16	"	1.0	-	2.1	5.0	-	0-2	0.65	0.75	Excellent
17	"	2.5	2.8	-	5.0	1.8	-	0.66	0.75	Excellent
18	"	5.0	2.9	2.2	4.9	2.1	0-2	0.68	0.78	Excellent

As can be clearly seen in Table 2, no lubrication effects as desired could be achieved when PTFE was used as a lubricant unless over 5 wt% was added. However, if the content of PTFE added exceeded 30 wt%, the fluidity of the material was reduced when molding was carried out. Thus when PTFE is added, the amount should be in the range between 5 and 30 wt%.

When MoS_2 is used as a filler, the content in the range between 1 and 5% is optimum.

Example 2

In producing the plug 6, an epoxy resin was used as synthetic resin and glass beads of silica glass of a mean particle size of 10 μm were used as a filler Tests were conducted in the same manner as described by referring to Example 1

The results of the tests are shown in Table 3.

Table 3

Item / Specimen	Filler		Dimensional Accuracy (μm)						Connection Loss (dB)	Overall Results
	Kind	Content (%)	Out of Roundness	Concentricity	Straightness	Surface Roughness	Spacing between Ends of Plug and Optical Fiber: Mean Value	Spacing between Ends of Plug and Optical Fiber: Variations		
D		0	1.5	3.5	9.5	0.5	7.5	2-10	1.50	Poor
19	Silica Glass	10.5	1.4	3.3	9.0	0.5	4.0	2-7	1.15	Poor
20	"	21.0	1.3	3.2	8.2	-	3.8	2-6	1.10	Poor
21	"	27.8	-	3.0	6.6	0.5	3.5	2-6	1.10	Poor
22	"	29.5	1.2	2.5	5.5	0.6	2.0	1-3	0.70	Excellent
23	"	49.7	1.1	2.4	-	0.6	1.0	0-2	0.68	Excellent
24	"	69.5	1.2	2.2	2.0	-	0.6	0-1	0.60	Excellent
25	"	81.0	-	2.4	1.5	0.7	0.3	0-0.5	0.69	Excellent

Note: D refers to the use of an epoxy resin alone.

As can be seen in Table 3, when the plug 6 is produced by using an epoxy resin, it is desirable that glass beads be added as a filler in 30-80 wt%. When the glass beads exceeded 81 wt% in amount, the fluidity of the resin was reduced at the time of molding operation, resulting in lowered molding characteristic of the resin.

It is believed that the need to use a large content of filler in combination with the use of an epoxy resin as a material for producing the plug 6 is accounted for by the essential difference in nature between polycarbonate and epoxy resin and the difference in fluidity (viscosity) existing at the time of molding operation.

The amount of the lubricant necessary for application to compensate for insertion and withdrawing of the plug 6 was the subject of study in the same manner as described by referring to example 1.

The specimens used in the tests consisted of an epoxy resin added with silica glass in 69 wt%, and the lubricants included PTFE, MoS_2 and graphite.

The results are shown in Table 4.

Table 4

Item / Specimen	Filler		Dimensional Accuracy (μm)					Connection Loss (dB)		Overall Results
	Kind	Content (%)	Out of Roundness	Concentricity	Straightness	Surface Roughness	Variations Spacing between Ends of Plug and Optical Fiber	Initial Stage	After Insertion and Withdrawing	
D		0	1.5	3.5	9.5	0.5	2-10	1.50	1.80	Poor
26	PTFE	0.5	1.0	2.0	2.1	0.6	0-1	0.60	0.70	Excellent
27	"	1.0	2.0	2.0	2.0	-	0-1	0.60	0.68	Excellent
28	"	2.5	-	2.0	2.0	0.6	0-1	0.61	0.66	Excellent
29	"	5.0	1.1	-	-	0.6	0-1	0.65	0.70	Excellent
30	MoS_2	1.0	1.0	2.0	-	0.6	-	0.64	0.68	Excellent
31	"	2.5	1.0	-	2.0	-	0-1	0.63	0.65	Excellent
32	Graphite	1.0	1.0	2.0	2.1	0.6	0-1	0.65	0.70	Excellent
33	"	2.5	1.0	2.0	2.2	0.6	0-1	0.66	0.71	Excellent
34	"	5.0	1.1	2.0	2.3	0.65	0-1	0.66	0.71	Excellent

As can be clearly seen in Table 4, it was possible to reduce the connection loss after insertion and withdrawing of the plug 6 when a lubricant was used. The amount of the lubricant added is preferably in the range between 1 and 5 wt% or achieving best lubrication effects and obtaining optimum formability.

In order to minimize the connection loss, it is essential that the outer diameter D_1 (Fig. 4) of the optical fiber 2 of the optical fiber cable 1 and the inner diameter d_1 (Fig. 3) of the orifice 8 of the plug 6 and the outer diameter D_2 (Fig. 3) of the forward end portion of the plug 6 and the inner diameter d_2 (Fig. 5) of the through hole 11 of the sleeve 10 be controlled.

First of all, in order to align the center axis of the optical fiber 2 with the center axis of the orifice 8 of the plug 6, the inner diameter d_1 of the orifice 8 has only to be made equal to the outer diameter D_1 of the optical fiber 2. However, if the inner diameter d_1 of the orifice 8 were equal to the outer diameter D_1 of the optical fiber 2, difficulties would be experienced in passing the optical fiber 2 through the orifice 8 and in addition no gaps would be formed between the orifice 8 and optical fiber 2 for admitting the adhesive agent thereinto. Meanwhile if the diameter d_1 were larger than the outer diameter D_1 of the orifice 8, eccentricity of the axes of the orifice 8 and the conductor 2 would become great. To overcome these difficulties, the inner diameter d_1 of the orifice 8 should

be larger than the outer diameter D_1 of the optical fiber 2 by 1-2 μm. This facilitates insertion of the optical fiber 2 in the orifice 8 and makes it possible to restrict the eccentricity of the orifice 8 and optical conductor 2 to 0.5-1 μm, in addition to facilitating admission of the adhesive agent between the optical fiber 2 and orifice 8 to achieve bonding between them.

The outer diameter D_2 of the plug 6 and the inner diameter d_2 of the sleeve 10 are decided by the force exerted for inserting and withdrawing the plug 6 and the connection loss. For example, Fig. 6 shows the force for inserting and withdrawing the plug 6 with respect to the sleeve 10 in relation to the connection loss, it being assumed that the difference (D_2-d_2) between the outer diameter D_2 of the plug 6 and the inner diameter d_2 of the sleeve provides a clearance necessary for fitting the plug 6 in the sleeve 10. In Fig. 6 in which A represents the insertion and withdrawing force and B indicates the connection loss, the plug 6 and the sleeve 10 used in combination were molded of an epoxy resin added with 69% of filler. When the fitting clearance is in the region (-), it is indicated that the plug 6 is force fitted in the sleeve 10, and the insertion and withdrawing force is high while the connection loss is small. On the other hand, when the fitting clearance is in the region (+), it will be seen that although the insertion and withdrawing force is low the connection loss is great.

Fig. 7 shows the number of times the plug is inserted and withdrawn in relation to changes in the connection loss with respect to a connection loss of the initial stages. In Fig. 7, a represents the fitting clearance being -3 μm at initial stages, and b indicates the fitting clearance being -2 μm at initial stages. As can be clearly seen in Fig. 7, the greater the fitting clearance in the (-) region, the higher became the frictional force acting between the plug 6 and the sleeve 10 when the former was inserted or withdrawn. This caused greater wear on the parts, so that the connection loss showed larger changes.

In view of the foregoing, it would be possible to keep the connection loss including the influences of insertion and withdrawing of the plug 6 to a level below 1 dB if the fitting clearance of the plug 6 in the sleeve 10 were set in the range between -3 and +2 μm.

Fig. 8 shows the influences exerted by the combination of the plug 6 and the sleeve 10 on connection losses. In Fig. 8, A1 represents the sleeve 10 formed of an epoxy resin and the plug 6 of polycarbonate and B1 represents the plug 6 and sleeve 10 both formed of an epoxy resin (the fitting clearance is 0 when the temperature is 22 degrees). As can be clearly seen in the figure, the influences of the temperature can be eliminated if the same material is used. Thus the plug 6 and the sleeve 10 are preferably formed of the same material.

An adhesive agent of low viscosity (below 20 poise) is used as an adhesive agent. By adding a filler to the adhesive agent, it is possible to reduce the eccentricity of the center axis of the optical fiber 2 of the optical fiber cable 1 with respect to the center axis of the orifice 8 of the plug 6. For example, alumina powder of an average particle size of 0.3 μm may be added as a filler in 40-60 wt% to the adhesive agent when $d_1 = D_1 + 1$ μm. This gives a uniform distribution of the filler between the orifice 8 and the optical fiber 2, so that the eccentricity of the optical fiber 2 with respect to the orifice 8 can be reduced to a level below 0.2 μm at a maximum. The mean particle size of the filler is about 50-70% of the clearance between the orifice 8 and the optical fiber 2. A suitable material should be selected for the filler.

Fig. 9 shows another embodiment of the invention wherein parts similar to those shown in Fig. 1 are designated by like reference characters. A glass pipe 25 is attached to the optical fiber 2 of the optical fiber cable 1 and inserted in the bore 7 of the plug 6 where it is adhesively bonded to the plug pin 6 and the optical fiber 2.

This construction lends the optical fiber connector according to the invention to applications in which the connector is installed in places of large variations in temperature where the connector is subjected to repeated heating and cooling, for a monitoring

system for the piping or processing devices of chemical plants or a data transmission system built in the rolling mill of a steel making plant, for example.

More specifically, when the optical fiber connector 5 is subjected repeated heating and cooling at a temperature of 100 degrees or thereabout, the difference in thermal expansion between the optical fiber 2 of the optical fiber cable 1 and the plug 6 and the adhesive agent causes peeling of the adhesive agent, and when the adhesive agent is pushed out of the forward end of the plug 6 by thermal expansion, the optical fiber 2 is simultaneously pushed out. This reduces the reliability of the optical fiber connector 5 used in transmission of information.

This disadvantage can be eliminated by using the glass pipe 25, because the optical fiber 2 is restrained by the glass pipe 25 and prevented from sticking out of the plug 6 even if subjected to repeated heating and cooling.

CLAIMS:

1. In an optical fiber connector comprising a plug adhesively attached to an end of an optical fiber cable, a sleeve threaded at either end of an outer peripheral surface thereof and adapted to have said plug inserted from opposite ends into a center axis portion thereof, a cap nut threaded at one end of an inner peripheral surface thereof for fixing the plug to the sleeve, and a spring mounted on an outer peripheral portion of the plug so as to be located between the plug and the cap nut, the improvement wherein said plug is formed of a synthetic resin by using a mold including a core for defining a forward end of the plug having a core pin of a larger than the optical fiber by 1 to several μm attached to said core and adapted to be abutted at one end by another core extending from the other side, so that the plug and the sleeve can be formed of a synthetic resin of the same composition.

2. An optical fiber connector as claimed in claim 1, wherein the synthetic resin composition molding said plug and said sleeve comprises polycarbonate, and one of glass beads, glass balloons and silica glass in particle form added to the polycarbonate in 10-30 wt% as a filler.

3. An optical fiber connector as claimed in claim 1, wherein the synthetic resin composition molding said plug and said sleeve comprises an epoxy resin, and one of glass beads, glass balloons and silica glass in particle form added to the epoxy resin in 30-80 wt%,

preferably in 50-80 wt%, as a filler.

4. An optical fiber connector as claimed in claim 1, wherein said plug has an outer diameter greater than the inner diameter of said sleeve by +3 to -2 μm.

5. An optical fiber connector as claimed in claim 1, wherein the adhesive agent used for connecting the optical fiber to the plug comprises an epoxy resin base adhesive agent of below 20 poise in viscosity.

6. An optical fiber connector as claimed in claim 1, wherein the adhesive agent comprises an epoxy resin base adhesive agent of below 20 poise in viscosity added as a filler with 40-60 wt% of alumina or aluminum hydroxide in particle form of mean particle size which is 50-70% of the clearance between an orifice of the plug and the optical fiber.

7. An optical fiber connector as claimed in claim 1, wherein a glass pipe is inserted into the root of the optical fiber and inserted together with the optical fiber into the plug, to thereby affix the glass pipe to the plug together with the optical fiber.

8. An optical fiber connector as claimed in claim 2, wherein the composition for molding the plug and the sleeve is added with 5-30 wt% of polytetrafluoroethylene as a lubricant.

9. An optical fiber connector as claimed in claim 2, wherein the composition for molding the plug and the sleeve is added with 1-5 wt% of molybdenum disulfide as a lubricant.

10. An optical fiber connector as claimed in claim 3, wherein the composition for molding the plug and the sleeve is added with 1-5 wt% of one of polytetrafluoroethylene, molybdenum disulfide and graphite as a lubricant.

11. A method of producing an optical fiber connector comprising the steps of:

removing in a predetermined length each of a secondary coat and a primary coat of an optical fiber cable at one end portion thereof and cleaning the outer peripheries of the exposed portions of the primary coat and an optical fiber with an organic solvent;

fitting a cap nut and a spring over the optical fiber at its end portion from which the coats have been removed;

introducing a predetermined amount of adhesive agent into an orifice of a plug;

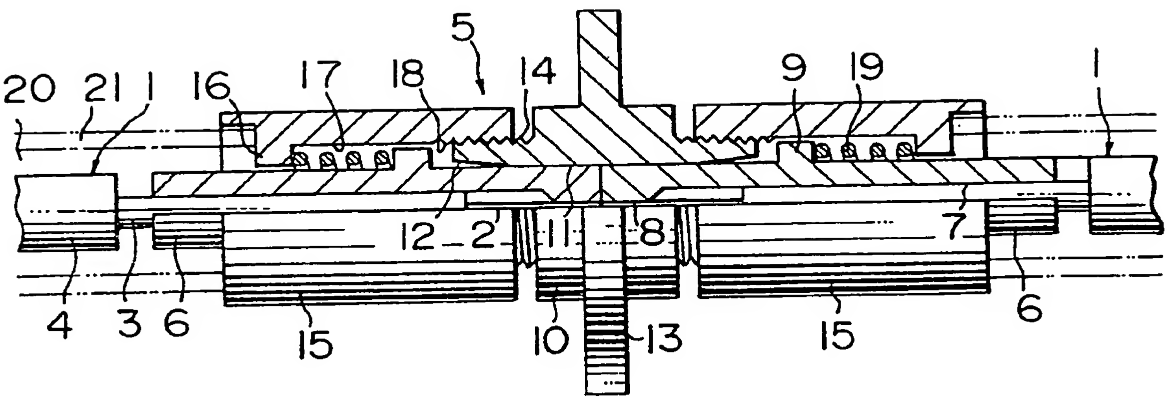
inserting the optical fiber cable into the plug until the optical fiber sticks out of the forward end face of the plug before the adhesive agent inserted in the plug sets; and

cutting the length of the optical fiber sticking out of the forward end face of the plug after the plug and the optical fiber are affixed to each other as a unit following setting of the adhesive agent and lapping the end faces of the plug and the optical fiber to provide mirror-like surfaces.

12. A method as claimed in claim 11, wherein a mold

used for molding the plug comprises a core for defining the forward end face of the plug, a core pin of a diameter larger by 1 to several μm than the diameter of the optical fiber to be connected attached to the center of said core and projecting therefrom, and a movable core extending from the rear end of the plug for abutting one end of said core.

F I G. 1


20
21
1
16
17
18
5
14
9
19
1
12
2
11
8
7
4
3
6
15
10
13
15
6

F I G. 2

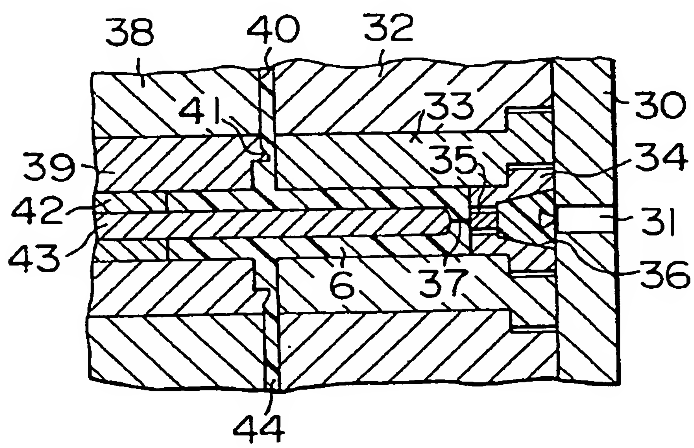

38
40
32
41
33
30
39
35
34
42
31
43
6
37
36
44

FIG. 3

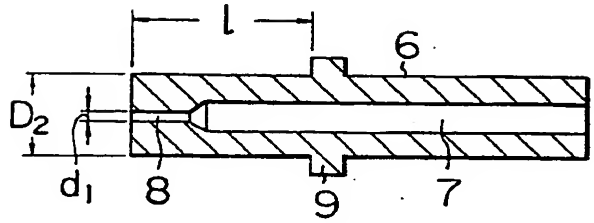


FIG. 4

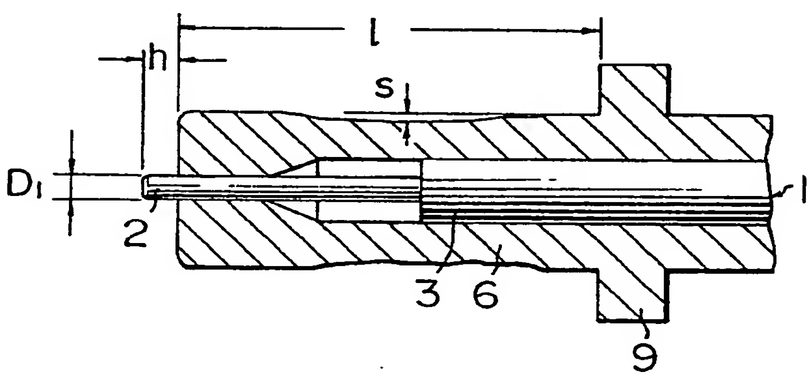


FIG. 5

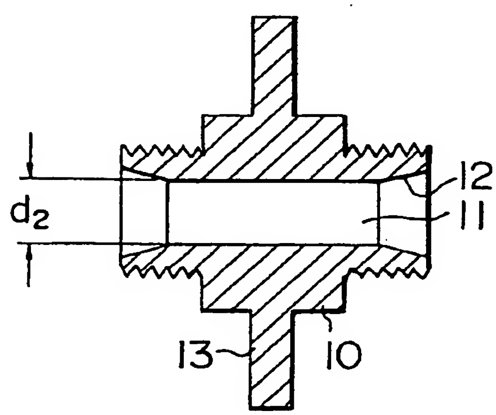


FIG.6

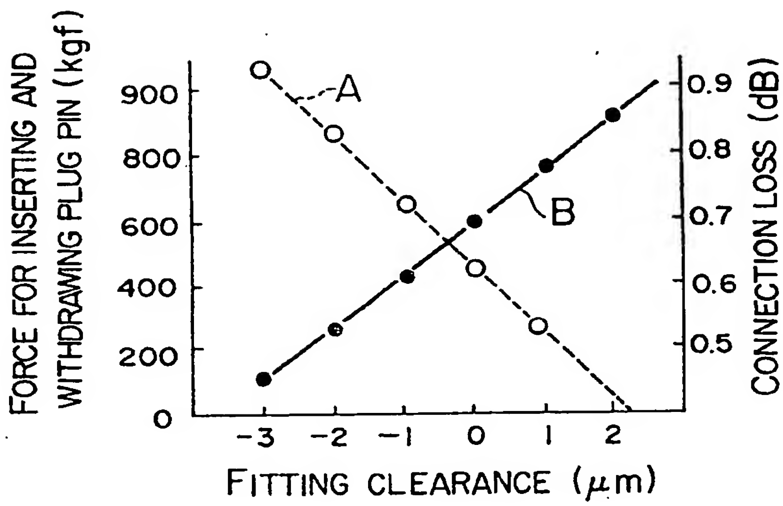

FORCE FOR INSERTING AND WITHDRAWING PLUG PIN (kgf)
900
800
600
400
200
0
A
B
0.9
0.8
0.7
0.6
0.5
CONNECTION LOSS (dB)
−3
−2
−1
0
1
2
FITTING CLEARANCE (μm)

FIG.7

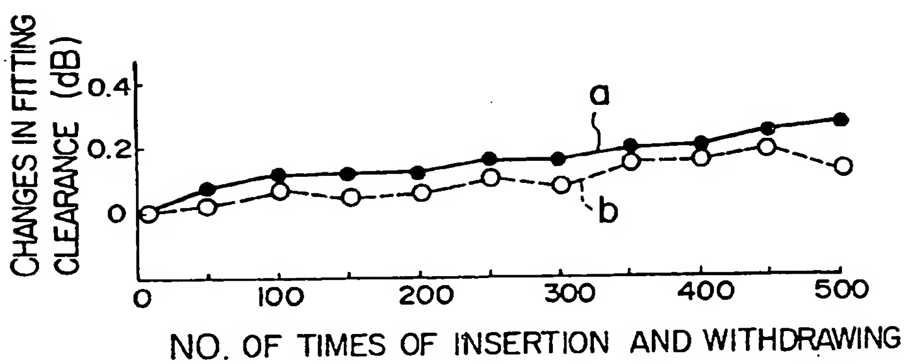

CHANGES IN FITTING CLEARANCE (dB)
0.4
0.2
0
a
b
0
100
200
300
400
500
NO. OF TIMES OF INSERTION AND WITHDRAWING

FIG. 8

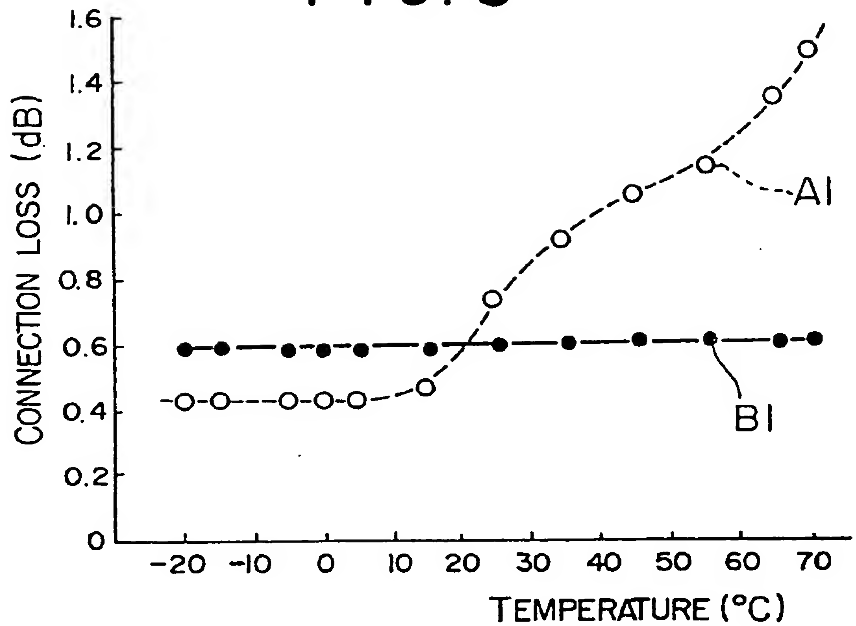
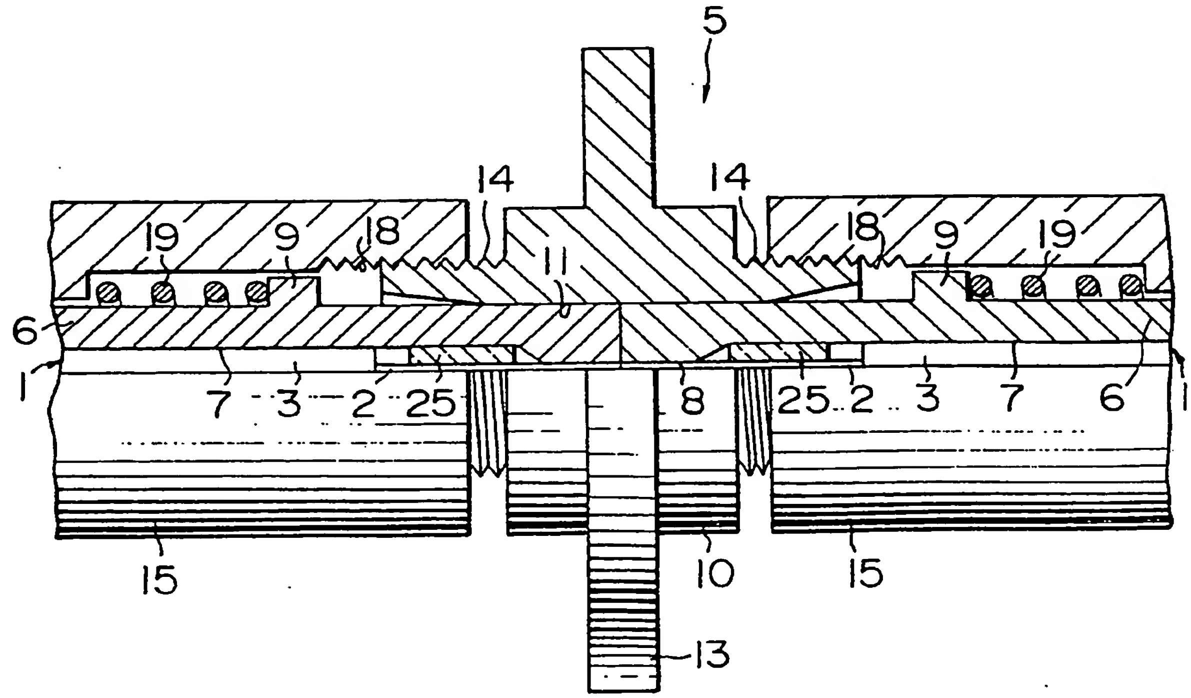

CONNECTION LOSS (dB)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
-20
-10
0
10
20
30
40
50
60
70
TEMPERATURE (°C)
A1
B1

FIG. 9


5
14
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19
9
18
11
18
9
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6
1
7
3
2
25
8
25
2
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7
6
1
15
10
15
13